

It resembles in its component parts the desert of Arizona. (4) The semi-arid region of eastern central Brazil, including most of Bahia and Pernambuco. It is very similar to the desert region of Santo Domingo and the typical genera are nearly all West Indian. (5) The desert of southern Brazil. This region we have not yet studied. (6) The states of Rio de Janeiro and São Paulo and the southern part of Minas Geraes, Brazil.

The last region is one of abundant rainfall and where all ordinary cacti would be killed. Here, however, the cacti not only grow on rocky knobs and along the beaches, but especially on the trunks of trees. Under the last named condition these plants find the same zerophytic conditions that their relatives find which grow in New Mexico and western Texas. They attach their roots to the bark of trees, their stems are reduced to long, shoe-string-like bodies, while the spines are reduced to hairs or they disappear altogether. About 40 of these epiphytic species, mostly belonging to the genus *Rhipsalis*, have developed in this region and they represent a most interesting group.

We have made large collections in South America in the fields visited; and we have ascertained that many species of cacti had never before been collected, and that many of those which had been collected had been poorly described and often wrongly classified.

ON THE ALBEDO OF THE PLANETS AND THEIR SATELLITES

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1. The most suitable definition of albedo for astronomical purposes appears to be that proposed by Bond¹ in 1861, namely, the ratio of the whole amount of light reflected in all directions from a sphere illuminated by parallel rays to the amount of light incident on the sphere.

2. The albedo A of any planet, according to this definition, is the product of two factors, one of which depends only on the size of the planet, its distances from the earth and sun, and its brightness at the full phase, while the other depends upon the way in which the brightness varies at different phases. The first factor, which may be called p , can be calculated from known data for all the planets. Its value depends mainly upon the material of the surface, being high if this is nearly white, and low if it is dark colored. The second factor, q , can be computed only when the planet is observable over a considerable range of phase, so that the law of variation of its brightness with phase can be determined, and its values are known only for the moon and the planets

of the terrestrial group. For Jupiter and the remoter planets, however, estimates can be made which are not likely to be much more than 15% in error. This factor depends mainly upon the *texture* of the planet's surface, being high if this is smooth, and low if it is rough and covered with irregularities whose shadows darken considerable areas at phases remote from the full.

3. The relative brightness of the sun and stars, as seen from the earth, has been determined with surprising accuracy,—the results of several observers, by radically different methods, being in excellent agreement. The sun's stellar magnitude, on the Harvard scale, according to the mean of the observations of Zöllner, Ch. Fabry, Ceraski and W. H. Pickering, is -26.72 ± 0.04 ,—which is equivalent to saying that the sun appears to be 123 thousand million times as bright as a standard first magnitude star. The photographic magnitude of the sun, according to King and Birck, is -25.93 , and its color index $+0.79$, agreeing very closely with the average for stars of similar spectrum (Class G).

4. The law of variation of the moon's brightness with phase is very well determined by the observations of J. Herschel, Bond, Zöllner, W. H. Pickering, King, Stebbins and Brown, and Wislicenus,—the results of all seven agreeing satisfactorily with a mean curve. The full moon is 8.7 times brighter than the first quarter, and 10.0 times brighter than the last quarter. The remarkable falling off in brightness between the full and half moon shows that the lunar surface must be very rough, as was first pointed out by Zöllner. The difference between the waxing and waning moon arises from the greater extent of the dark *maria* on the eastern half of the visible disk (as Stebbins has shown).

5. The results of different observers for the brightness of the mean full moon, compared with the sun or stars, are discordant. J. Herschel's observations² have been reduced anew, and an error which had crept into the earlier reduction corrected. The weighted mean of those determinations which are not obviously affected by systematic error makes the visual magnitude -12.55 , and the ratio of sunlight to mean full moonlight 465,000, —with an uncertainty of fully 10%. The photographic magnitude, -11.37 , has been well determined by King. It shows that moonlight is redder than sunlight.—in agreement with the spectro-photometric measures of Wilsing and Scheiner.

6. Müller's data for the major planets³ have been adopted, with a correction of -0.06 mag. to reduce to the Harvard scale, except for Uranus and Neptune; Pickering's magnitudes for the asteroids,⁴ and Guthnick's for the satellites of Jupiter and Saturn.⁵ The color indices of Venus, Mars, Jupiter and Saturn have been derived from comparison of Müller's visual and King's photographic observations.⁶

7. Very's observations of the intensity of the earthshine⁷ indicate that the mean full earth, as seen from the moon, appears 40 times as bright as the mean full moon, seen from the earth, and that the stellar magnitude of the earth, as seen from the sun, would be about -3.5 , with an uncertainty of at least 25%, or 0.20 mag.

8. The intensity of sunlight from the zenith, according to H. H. Kimball, is 103,000 metre-candles. That of mean full moonlight, according to several observers, is 0.24 metre-candle. A standard candle, if of approximately the same color as the stars, would appear as bright as a star of the first magnitude if placed at a distance of 1.09 kilometres.

9. Table 1 gives the values finally derived for the albedo of the various planets and satellites, and related quantities.

Object	TABLE I		Semi-diameter	p	q	Albedo A	Color-Index	Photographic Albedo
	Mag. at Mean Opp.	Mag. at Unit Distance						
Moon.....	-12.55	+0.40	2'.40	0.105	0.694	0.073	+1.18	0.051
Mercury.....	- 2.94	-0.88	3.45	0.164	0.42	0.069	.....	.....
	- 2.12	-0.06		0.077	0.72	0.055	.....	.....
Venus.....	- 4.77	-4.06	8.55	0.492	1.20	0.59	+0.78	0.60
Mars.....	- 1.85	-1.36	4.67	0.139	1.11	0.154	+1.38	0.090
Jupiter.....	- 2.29	-8.99	95.23	0.375	1.5:	0.56:	+0.50	0.73:
Saturn.....	+ 0.89	-8.67	77.95	0.420	1.5:	0.63:	+1.12	0.47:
Uranus.....	+ 5.74	-6.98	36.0	0.42	1.5:	0.63:	.....	.....
Neptune.....	+ 7.65	-7.00	34.5	0.49	1.5:	0.73:	.....	.....
Ceres.....	+ 7.15	+3.70	0.53	0.10	0.55:	0.06:	.....	.....
Pallas.....	+ 7.84	+4.38	0.34	0.13	0.55:	0.07:	.....	.....
Juno.....	+ 8.95	+5.74	0.14	0.22	0.55:	0.12:	.....	.....
Vesta.....	+ 6.04	+3.50	0.27	0.48	0.55:	0.26:	.....	.....
Jupiter								
Satellite I.....	+ 5.54	-1.16	2.38	0.46	1.5:	0.69:	.....	.....
" II.....	+ 5.69	-1.01	2.08	0.51	1.5:	0.76:	.....	.....
" III.....	+ 5.08	-1.62	3.62	0.30	1.5:	0.45:	.....	.....
" IV.....	+ 6.26	-0.44	3.49	0.11	1.5:	0.16:	.....	.....
Titan.....	+ 8.30	-1.26	2.9	0.33	1.5:	0.50:	.....	.....
The Earth								
Lommel-Seeliger law.....	-3.46		8.79	0.27	1.64	0.45	.....	.....
Lambert's law.....	-3.52		"	0.29	1.50	0.43	+0.45?	0.6?
Observed law for Venus.....	=3.80		"	0.37	1.20	0.45	.....	.....
" " " Moon.....	-4.40		"	0.65	0.70	0.45	.....	.....

Column 2 gives the stellar magnitude at mean opposition (in the case of Mercury and Venus, at full phase, unit distance from the earth, and mean distance from the sun); column 3 the magnitude for full phase and unit distance from the sun and the observer; column 4 the adopted mean angular semidiameter at unit distance; the next three columns, the values of p , q , and A , defined as above; and the last two, the color-index and the photographic albedo (A) in the cases where these are

known. Two sets of values are given for Mercury, corresponding to the two empirical formulae for the variation of its brightness with phase given by Müller, and four for the earth, representing the results derived from Very's observations on the assumption that the variation of the brightness of the earth with phase follows four different laws, derived from theory or from observation of other bodies.

10. These values of the albedo of the various bodies are in entire agreement with the current views of their constitution. For Venus and the outer planets, which are generally supposed to be covered with clouds, the albedo is very near the value found by Abbot for terrestrial clouds (0.65). For Mars, Mercury and the moon the albedo is comparable with that of ordinary rocks, as it is also for three of the four asteroids. Even the high value for Vesta can be matched by some whitish terrestrial rocks; but the still higher values for the inner satellites of Jupiter are rather remarkable.

11. The value here found for the earth's albedo is intermediate between those of the cloudy and cloudless planets, and agrees very closely with Abbot's estimate⁸ of 0.37, based on the known cloudiness of the earth's atmosphere. It is only half as great as that which Very has derived from the same observations, but the discrepancy is easily explicable. The discussions of the observations by Very and by the writer agree in showing that the albedo of the earth (more precisely, the value of the constant called p above) is a little more than five times as great as that of the moon (if Zöllner's value for the brightness of the latter is adopted). But the value of the moon's albedo used by Very (0.174) is what Zöllner⁹ calls the "true albedo"—which is the value obtained after a large and very uncertain correction for the assumed influence of the irregularities of the surface, according to a theory which has later been found to contain a serious error.¹⁰ Zöllner's observations themselves lead to the value 0.080 for p , and when this correction is made, the discrepancy disappears.

The full paper, with much more extensive references, will be published in the *Astrophysical Journal*.

¹ *Proc. Amer. Acad. Arts Sci.*, 8, 232 (1861).

² *Results of Astronomical Observations made at the Cape of Good Hope* (London, 1847), pp. 353–374.

³ *Potsdam Pub. Astrophysik.*, Bd. 8, Tl. IV (1893).

⁴ *Harvard Coll. Obs. Cir.*, No. 169 (1911).

⁵ *Astr. Nachr.*, 198, 251 (1914).

⁶ *Ann. Obs. Harvard Coll.*, 59, 261–264.

⁷ *Astr. Nachr.*, 196, 269–290 (1912).

⁸ *Smithsonian Inst., Ann. Astrophys. Obs.*, 2, 161–163.

⁹ *Photometrische Untersuchungen* (Leipzig, 1865), p. 162.

¹⁰ See Müller, *Photometrie der Gestirne* (Leipzig, 1897), p. 77.